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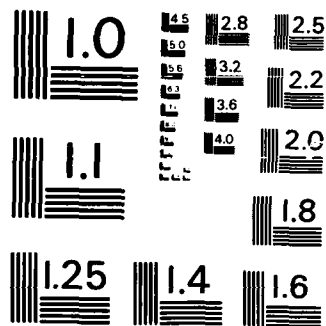
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**AIR FORCE** 

**HUMAN RESOURCES**

**INTEGRATED COMMUNICATION, NAVIGATION, AND  
IDENTIFICATION AVIONICS: IMPACT ANALYSIS**

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*(12)*

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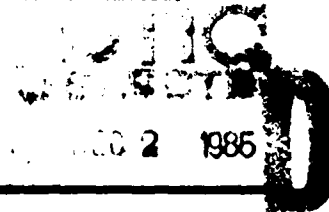
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19 ABSTRACT (Continue on reverse if necessary and identify by block number) This paper summarizes the research into reliability, supportability, and survivability prediction techniques for fault-tolerant avionics systems. It outlines applications of these systems to Integrated Communication, Navigation, and Identification Avionics. An overview of the Mission RELiability Model (MIREM) is also presented. MIREM is a new method for analyzing fault tolerance in reconfigurable systems.					
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IDENTIFICATION AVIONICS: IMPACT ANALYSIS

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## SUMMARY

This paper summarizes the approach and findings of research into reliability, supportability, and survivability prediction techniques for fault-tolerant avionics systems. Since no technique existed to analyze the fault tolerance of reconfigurable systems, a new method was developed and implemented in the Mission Reliability Model (MIREM). The supportability analysis was completed by using the Simulation of Operational Availability/Readiness (SOAR) model. Both the Computation of Vulnerable Area and Repair Time (COVART) model and FASTGEN, a survivability model, proved valuable for the survivability research. Sample results are presented and several recommendations are also given for each of the three areas investigated under this study.



## PREFACE

This paper documents research into reliability, supportability, and survivability prediction techniques for fault-tolerant avionics and their application to Integrated Communication, Navigation, and Identification Avionics. This work is jointly supported by the Air Force Human Resources Laboratory and the Air Force Wright Aeronautical Laboratories. The guidance and support of Messrs. James C. McManus, Daniel V. Ferens and Robert L. Harris of these organizations are greatly appreciated.

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## I. INTRODUCTION

The Impact Analysis of Integrated Communication, Navigation, and Identification Avionics (ICNIA) program, an overview of which is depicted in Figure 1, had the following goals:

1. Develop logistics analysis methods that are appropriate for design evaluation of integrated, fault-tolerant systems early in the development cycle.
2. Investigate traditional and innovative maintenance concepts; in particular, evaluate deferred repair policies that would exploit fault tolerance to increase sustainability in limited repair environments.
3. Apply these techniques to the two ICNIA architectures under development.

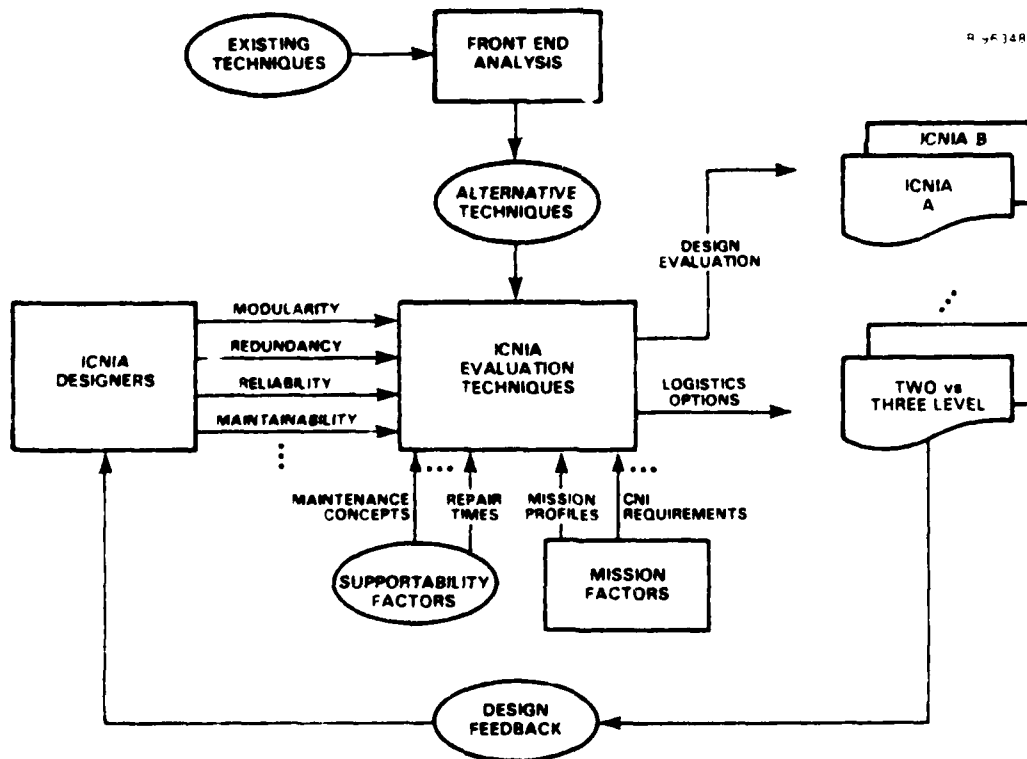


Figure 1. Overview of Impact Analysis ICNIA.

4. Influence the ICNIA designs to improve reliability and supportability.

5. Document the research and development results in a form amenable for use by design engineers.

One primary motivation for this research was that, historically, logistics engineering disciplines have been applied to new avionics designs in the later stages of development. To ensure that avionics designs are reliable, supportable, and survivable in the operating environment, logistics engineering techniques are needed that can be effectively implemented early in the development cycle. Use of these techniques will allow design engineers to provide for reliability, supportability, and survivability before the design is fixed.

Recent trends toward integration and fault tolerance in avionics also create a need for new techniques that capture these characteristics and can identify support concepts that exploit the fault-tolerant nature of the systems. In the ICNIA system, fault tolerance will be achieved through dynamic reconfiguration that allocates common system resources to a variety of radio functions across a wide spectrum of frequencies. Dynamic reconfiguration will allow faults to be managed and resources to be effectively shared between required functions. Because of its intended role as the sole communication set onboard tactical aircraft, system reliability and fault tolerance are of central importance to ICNIA.

## II. METHODOLOGY

### Reliability Analysis

A survey of existing techniques led to the conclusion that no single model in use by DoD both considers the complex relationships between system components found in ICNIA and provides simple enough data input structures to deal with a realistic number of system resources. As a result, a new method for analyzing fault tolerance in re-configurable systems was developed (Figure 2). Implemented in the Mission REliability Model (MIREM) computer program, this method analyzes a network structure of functional components. The Mission Completion Success Probability (MCSP) is computed for a specified mission, requiring certain Communication, Navigation, and Identification (CNI) functions. Measures such as Mean Time Between Critical Failure (MTBCF) and failure resiliency (a measure of fault tolerance) are also generated.

Results for a hypothetical architecture and two mission scenarios are shown in Table 1. Mission scenario 1 requires all the available resources in several parts of the system, resulting in very little fault tolerance. Relative to mission scenario 2, however, the system contains redundant resources which extend the Mean Time Between Failure (MTBF) from 224 hours to 1379 hours between critical failures (those that cause mission failure) without repair. Expressing this in terms of failure resiliency, roughly six failures can be sustained before a critical failure occurs. These representative results show that fault tolerance can dramatically prolong the operating time without repair of the system if the system contains redundancy relative to the mission requirements.

### Logistics Support Analysis

A logistics support analysis technique was sought that would relate design factors and support resources to readiness without imposing data requirements that are unrealistic during the early design phase. After a literature review, the Simulation of Operational Availability/Readiness (SOAR<sup>TM</sup>)<sup>1</sup> was selected for this purpose and modified to address fault tolerance. SOAR is a deterministic mean value simulation of the dynamics of aircraft sortie and maintenance operations at a single site. It considers the logistics parameters shown in Figure 3.

<sup>1</sup>SOAR is a trademark of The Analytic Sciences Corporation

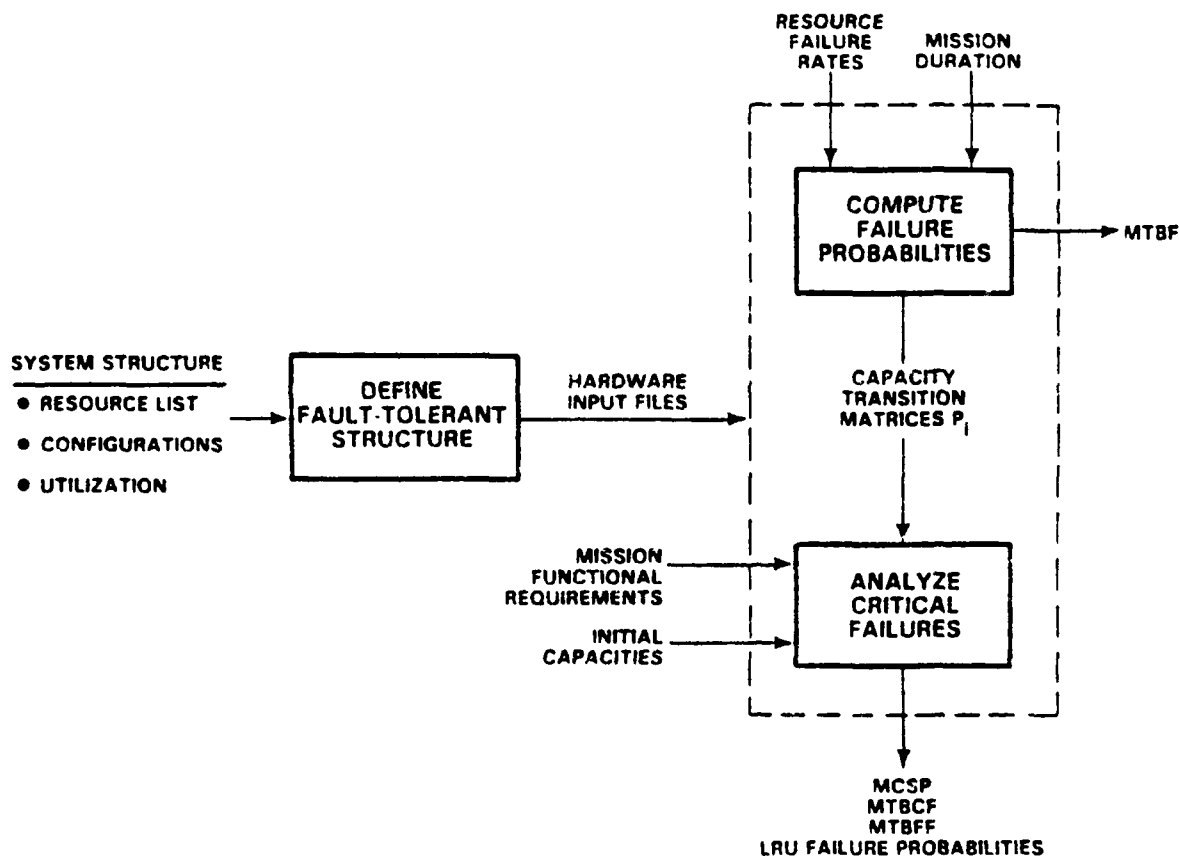


Figure 2. Mission Reliability Model (MIREM) Overview.

TABLE 1. SAMPLE RELIABILITY RESULTS

QUANTITY	MISSION SCENARIO	1 THREE FUNCTIONS REQUIRED SIMULTANEOUSLY	2 TWO FUNCTIONS REQUIRED SIMULTANEOUSLY
MCSP (3 hr MISSION)		0.9880	0.999996
MTBCF		249 hrs	1374 hrs
MTBF		224 hrs	224 hrs
FAILURE RESILIENCY		1.11	6.15

FAILURE RESILIENCY IS DEFINED AS MTBCF/MTBF.

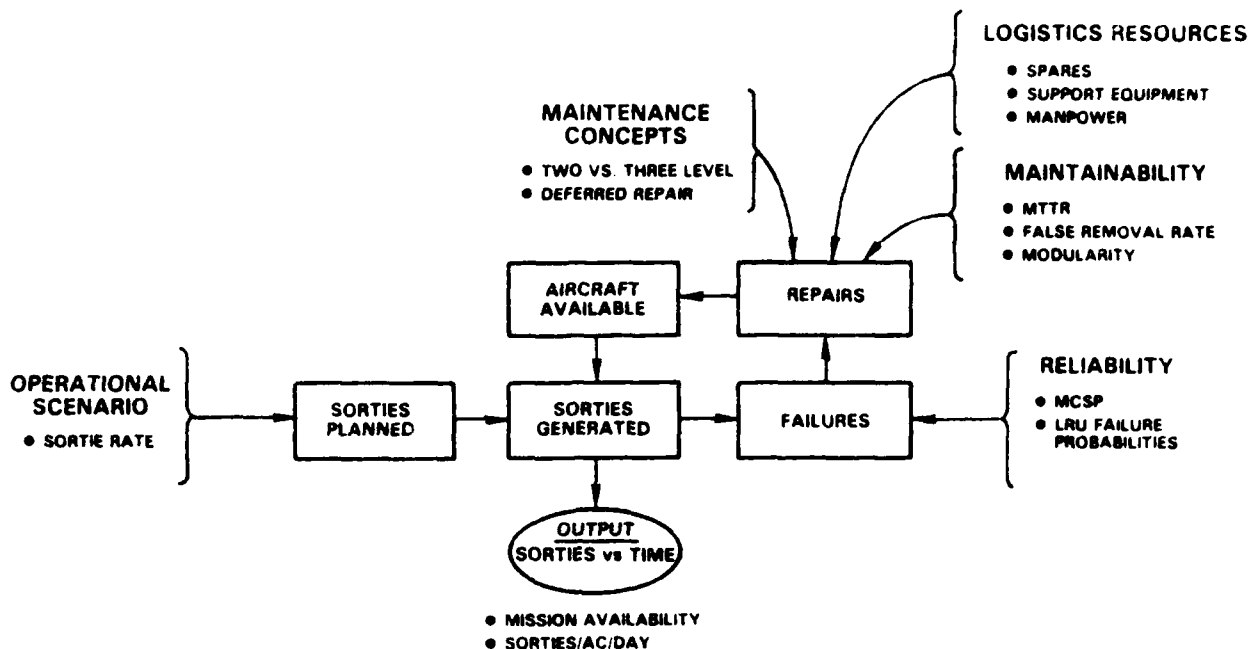


Figure 3. Readiness Methodology Overview.

The effect of deferring repair of noncritical failures until a critical failure occurs, in order to generate more sorties without maintenance downtime, can be explored using the model. Figure 4 quantifies the effect of deferred repair on the maximum sortie rate that can be supported by the hypothetical fault-tolerant ICNIA architecture discussed above. Under two-level support and the same spares levels, the deferred repair policy can sustain a high sortie rate without maintenance actions much longer than can the immediate repair policy, which quickly depletes the available spares.

#### Survivability Analysis

The role of ICNIA as the sole communication set onboard an aircraft could lead to the conjecture that ICNIA is more vulnerable to projectile threats than a suite of

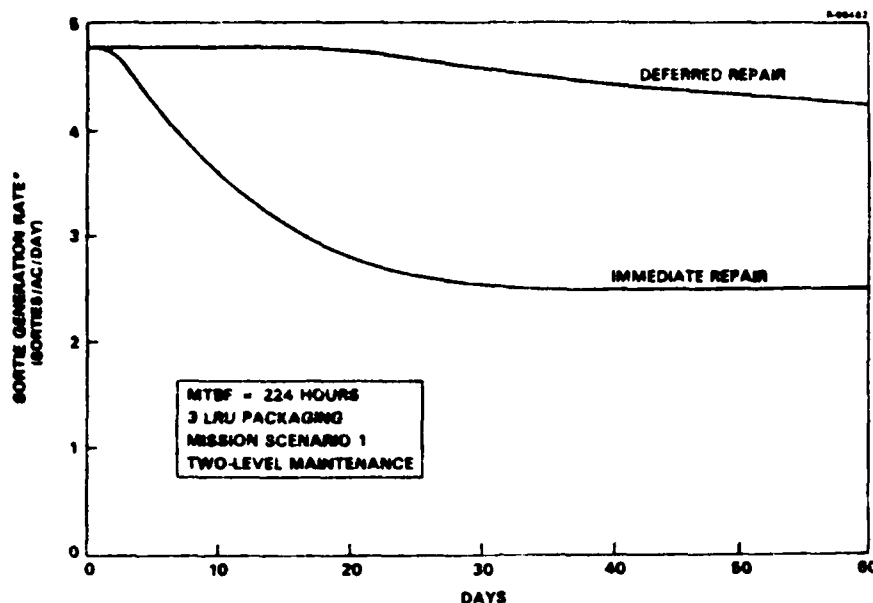


Figure 4. Maximum Sortie Generation by Repair Policy.

discrete CNI avionics would be. On the other hand, volume reduction, through system integration, makes ICNIA a smaller target. The vulnerability question also includes consideration of which Line Replaceable Units (LRUs) ICNIA can afford to lose and still retain a specified capability. A front end study disclosed that the FASTGEN and COVART computer programs are widely accepted for survivability analysis. However, a baseline CNI survivability analysis was not available because CNI is generally considered negligible when assessing aircraft vulnerability. A methodology for addressing ICNIA survivability was developed (Figure 5), extracting relevant portions of the FASTGEN and COVART programs.

Preliminary penetration assessment for typical LRU configurations in an avionics bay and representative projectile threats revealed that penetration through two LRUs was likely. Since ICNIA houses redundant components in at most two LRUs, these results indicate that CNI system kill will be highly dependent on explicit protection concepts and individual LRU placement. The key to survivability improvement of integrated systems over discrete systems lies in volume and weight reduction, which can be transformed into various protective measures.



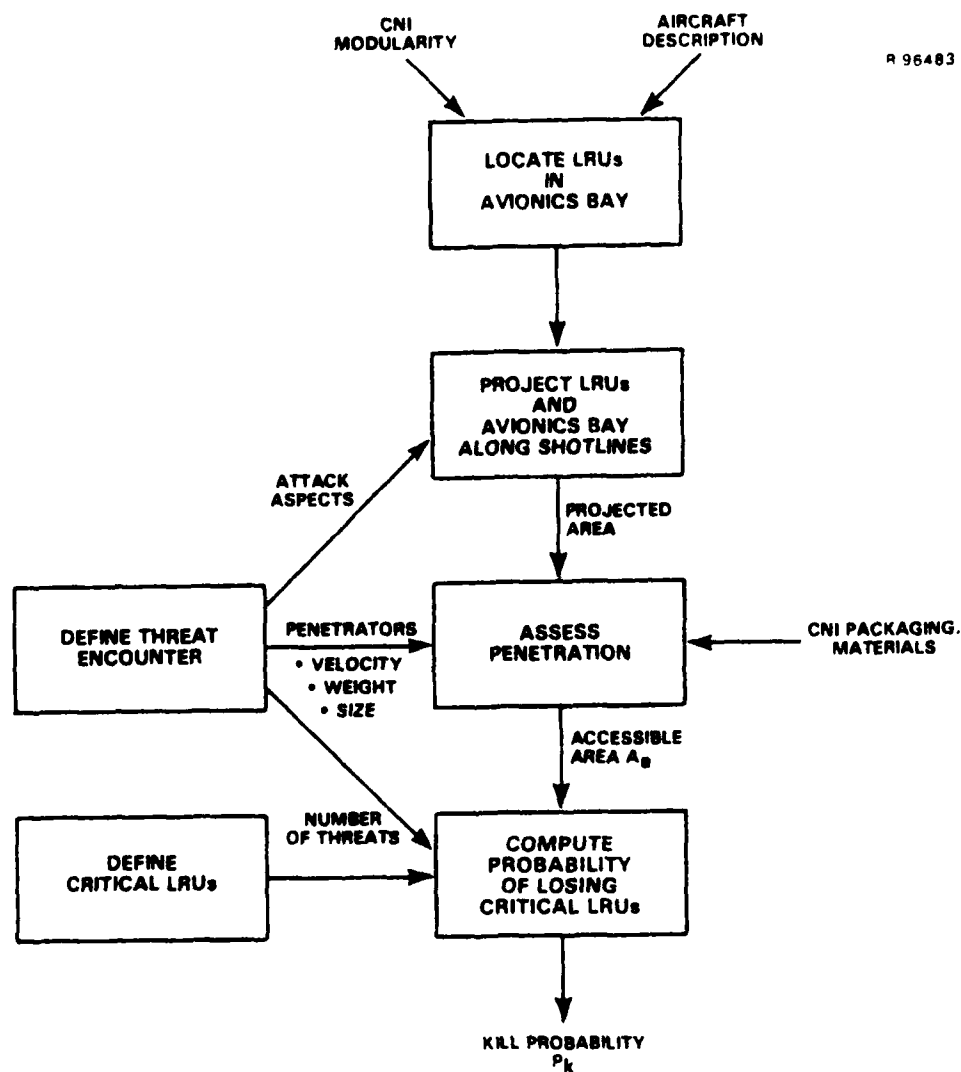


Figure 5. Overview of Survivability Methodology.

### III. CONCLUSIONS AND RECOMMENDATIONS

The methodologies for assessing reliability and logistics support impacts, presented herein, have been applied to the ICNIA architectures during the early stages of design. They are capable of analyzing the impacts of integration and fault tolerance in complex systems. Several general conclusions can be drawn from the ICNIA architectures analyzed. For reliability,

1. Single components that can cause system failures (critical failures), if they exist, are the single most important factor in MCSP.
2. A second level of redundancy (at the LRU level) improves reliability only if all critical functions are supported on both of the LRUs.
3. The determination of which functions are critical for a mission and whether they are required simultaneously can drastically affect MCSP.
4. Reconfigurability (e.g., inter-LRU connections) between components that are already redundant does not necessarily enhance reliability.

In terms of supportability,

1. Deferral of repair until a critical failure occurs allows a high sortie rate to be sustained for a longer period without repair. The payoff is substantial for highly fault-tolerant systems, particularly under a two-level maintenance policy. However, some penalty is paid in MCSP for flying systems that contain failed components (less redundancy).
2. High reliability, deferred repair policies and increased modularity all provide impetus to use two-level rather than three-level maintenance, thereby eliminating expensive intermediate-level test equipment.

The developed techniques have the advantage of not requiring highly detailed design and logistics inputs and of being relatively streamlined. The computerized models are amenable to interactive use and could be hosted on a minicomputer. As a result, the techniques can be applied early in the design phase as a design tool to aid the engineer in building reliability and supportability into an integrated system.

In the survivability area, the reduced volume and weight of ICNIA, compared to discrete systems, provide the key to decreased vulnerability by transforming them into increased protective measures. Preliminary results suggest the ICNIA system kill will be dependent on explicit protection concepts and LRU placement; therefore, detailed analysis appears more fitting when actual installation nears.

Several areas of additional research are suggested by this study. The reliability model developed here does not include the effects of incomplete or faulty built-in test coverage, which could cause incorrect switching by the system controller. For highly fault-tolerant systems, the effect of incorrect switching is likely to be significant. Software reliability and fault tolerance, which will become increasingly important in these systems, are also areas for which further research would prove useful. Maintenance concepts that rely on smart systems to schedule and reduce the number of repair actions pose another major issue. The implications of attempting to institutionalize such a concept need to be explored. Finally, enhancement and possibly integration of the models developed here into an interactive, user-friendly package is recommended in order to provide the capability to those individuals who most influence early system design--the design engineers.

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